ISSN: 2349-0845

IJRST

International Journal of Research in Science & Technology (IJRST)
Volume 1, Issue 2 : Page No. 1-10
www.ijrst.weebly.com

Three Phase VSI for Wind Generator with Hysteresis Current Controller

Pravin D.Kumbhar[1], Chaitanya J.Kadam[2], Dipak R.Shelar[3], Prof. S.S.Vanamane [4]

P.G. Student, Dept. of Electrical Engg. Walchand College of Engineering, Sangli (M.S.), India[123], E-mail Id: kumbharp07@gmail.com[1], chaitanyak1689@gmail.com[2], deep.shelar@indiatimes.com[3]

Assistant Professor, Dept. of Electrical Engg. Walchand College of Engineering, Sangli (M.S.), India[4].

Abstract: This paper represents the wind turbine with Permanent Magnet Synchronous Generator (PMSG) and Wind Energy Conversion System (WECS) that includes three phase rectifier system and three phase Inverter System with Hysteresis Current Controller. Hysteresis current controller leads to compensate the load side current harmonics. It also introduces the LC filter to remove load side harmonics.

Keywords: — Permanent Magnet Synchronous Generator (PMSG), Wind turbine, Hysteresis Current Controller (HCC), Voltage Source Inverter (VSI).

I. INTRODUCTION

The use of fossil fuel creates many environmental problems and these fuels are exhaustible in nature. Renewable energy source is one of the solutions for above problems. The wind energy is one of the renewable energy sources available in large amount and it is free of cost. The wind energy is available easily. The many governments providing incentives, hence use of renewable energy now days goes on increasing.

To extract energy from Wind, we generally use two kinds of generator with wind turbine. One is Permanent Magnet Synchronous Generator (PMSG) and Doubly Fed Induction Generator (DFIG).Generally we prefer PMSG, because it has certain advantages over DFIG such as, it has simple structure, has ability to operate at low speed, and has self-excitation capability leading to high power factor [1].

There are many configurations used for wind energy conversion such as, Back to Back converter, Modified Back to back converter, Power factor correction using PWM rectifier. AC power from wind generator is converted in to DC by uncontrolled rectifier and then it is boosted by Boost converter. Then this energy is converted in to AC by using Voltage Source Inverter. The three phase voltage source inverter is used with hysteresis current controller to provide AC power to load [7].

II. PROPOSED WIND ENERGY CONVERSION SYSTEM (WECS)

This WECS consist of wind turbine with PMSG and various power converters.
Wind energy supply system:
The system consist of Wind turbine with Permanent Magnet Synchronous Generator (PMSG), uncontrolled rectifier, three phase voltage source inverter.
Wind Turbine:

The wind power captured is given by following equation,

$$Pm = 0.5\rho A C p V_w^3 \quad (1)$$

Where,
P_m= Mechanical power captured by wind turbine.
ρ= Air density Kg/m^3.
A=Area swept by rotor m^2.
C_p=Power coefficient of the wind turbine.
v_w=Wind speed in m/sec.

ISSN: 2349-0845

International Journal of Research in Science & Technology (IJRST)
Volume 1, Issue 2 : Page No. 1-10
www.ijrst.weebly.com

Power coefficient (C_p) is the function of Tip speed ratio (λ) and Pitch angle (β).In our case pitch angle is zero so that the power coefficient is the function of tip speed ratio. The relation is expressed by following equation [2],

$$Cp(\lambda) = \left[\frac{60.04-4.69\lambda}{\lambda}\right] e^{\left[\frac{-21+0.735\lambda}{\lambda}\right]} + \left[\frac{0.0068\lambda}{1-0.025\lambda}\right] \tag{2}$$

$$\lambda = \frac{\omega_r R}{v_w} \tag{3}$$

Where,
R= Radius of blade in meter.
$\omega_r =$ Rotational speed (Rad/second).
The figure 1 shows the characteristics between power coefficients (C_p) and tip speed ratio (λ) for various values of beta (β).From this graph we conclude that we get maximum C_p when pitch angle β is zero. From graph it is observed that for fixed pitch Angle when tip speed ratio is at optimal value (λ_{opt}) we get maximum $C_{p[3]}$.

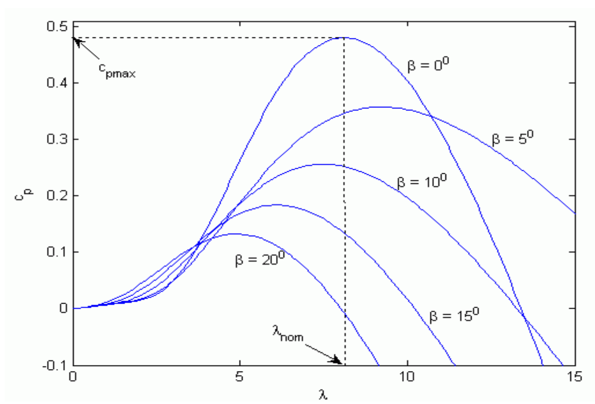

Fig. 1. The relation between Power coefficient (C_p) and Tip speed ratio (λ).

Optimal wind turbine power is given by following equation,

$$P_{m\_opt} = 0.5\rho A C_{p\_opt} \left[\frac{\omega_{r\text{-}opt} R}{\lambda_{opt}}\right]^3 \tag{4}$$

$$\omega_{r\_opt} = \frac{\lambda_{opt}}{R} v_w \tag{5}$$

From above equation and graph it is seen that for some wind speed mechanical power (P_m) varies with respect to rotor speed (ω_r).With every wind speed we get maximum power at optimal rotor speed (ω_r).

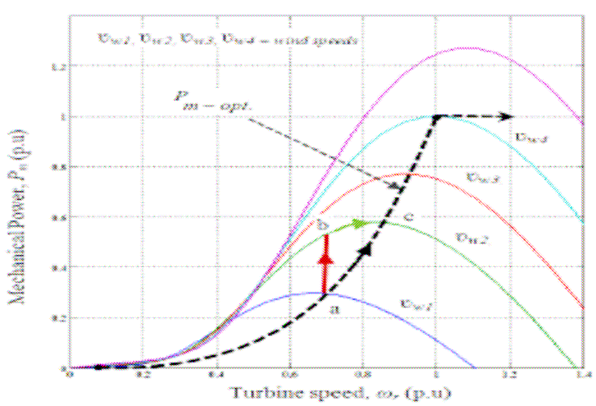

Fig.2. The relation between mechanical power (P_m) and rotor speed (ω_r).

ISSN: 2349-0845

IJRST

International Journal of Research in Science & Technology (IJRST)
Volume 1, Issue 2 : Page No. 1-10
www.ijrst.weebly.com

1. Permanent Magnet Synchronous Generator (PMSG):

Figure3 shows the equivalent circuits of Permanent Magnet Synchronous Generator based on the wind energy conversion system.

The voltage equations of PMSG are given by,

$$\frac{d}{dt}i_d = \frac{1}{L_d}v_d - \frac{R}{L_d}i_d + \frac{L_q}{L_d}p\omega_r i_q \quad (6)$$

$$\frac{d}{dt}i_q = \frac{1}{L_q}v_q - \frac{R}{L_q}i_q - \frac{L_d}{L_q}p\omega_r i_d - \frac{\lambda p\omega_r}{L_q} \quad (7)$$

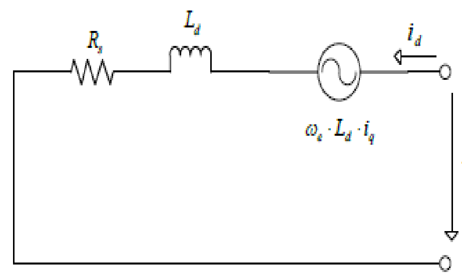

Fig. 3.d-axis equivalent circuit of PMSG.

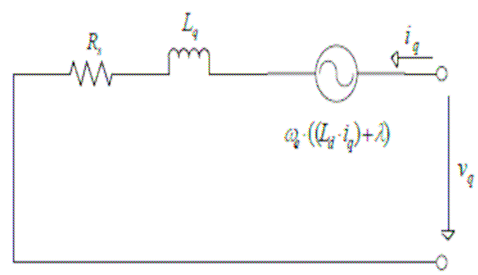

Fig. 4.q-axis equivalent circuit of PMSG.

The dynamic equation is given by,

$$\frac{d}{dt}\omega_r = \frac{1}{J}(T_e - F\omega_r - T_m) \quad (8)$$

$$\frac{d}{dt}\Theta = \omega_r \quad (9)$$

Where,
J= Inertia of rotor
F= friction of rotor
Θ= rotor angular
The electromagnetic torque equation is given by,

$$T_e = 1.5p[\lambda i_q + (L_d - L_q)i_d i_q] \quad (10)$$

Where,

L_q = q axis inductance,

L_d = d axis inductance,

R = Resistance of stator winding,

i_d = d axis current

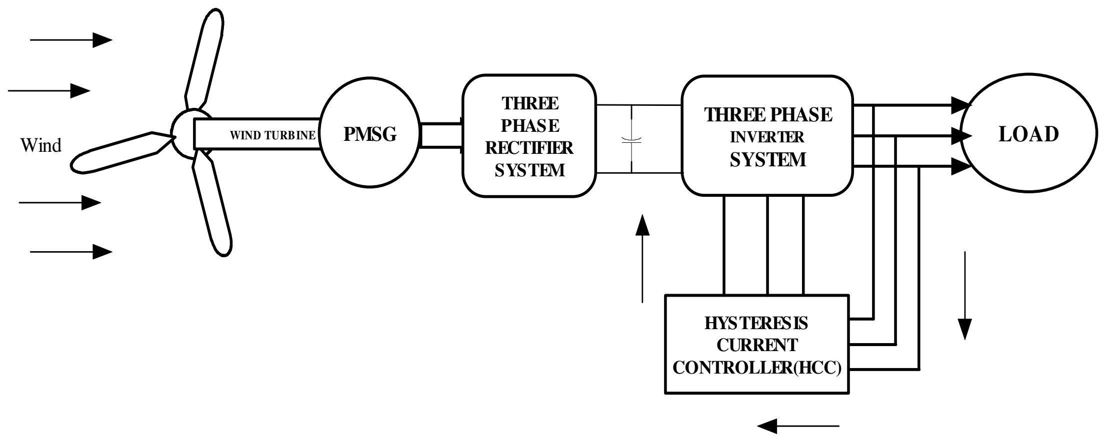

Fig.5. Block Diagram of Wind Energy Conversion System.

i_q = q axis current

v_q = q axis voltage

v_d = d axis voltage

ω_r = Angular velocity of rotor

λ = Amplitude of flux induced

p = number of pole pairs.

2. Wind Energy Conversion System (WECS):

This System consist of Wind turbine with permanent Magnet Synchronous generator, three phase Rectifier and Three phase Voltage source Inverter with hysteresis Current Controller. Figure Shows the Block Diagram of overall system.

3. Three phase Voltage Source Inverter (VSI):

Three phase voltage source inverter is used to convert AC power to load. The DC power from three phase rectifier is received by three phase inverter and then it is converted in to AC power by using hysteresis current controller. The figure shows the circuit diagram for three phase VSI [4].

ISSN: 2349-0845

International Journal of Research in Science & Technology (IJRST)
Volume 1, Issue 2 : Page No. 1-10
www.ijrst.weebly.com

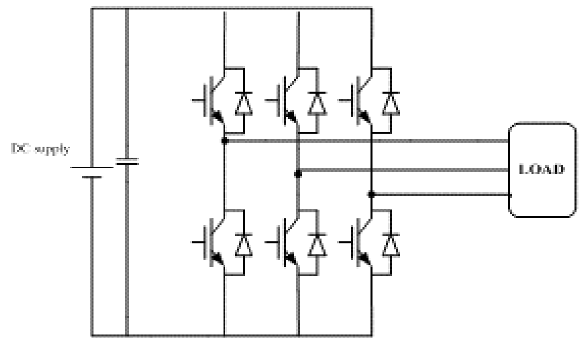

Fig. 6.Circuit Diagram of Three phase Voltage Source Inverter.

4. Hysteresis current controller:

It is close loop system. In this control system the hysteresis band is created and actual current is forced to follow reference current within that band. Figure shows the basic principal of hysteresis current controller [7].

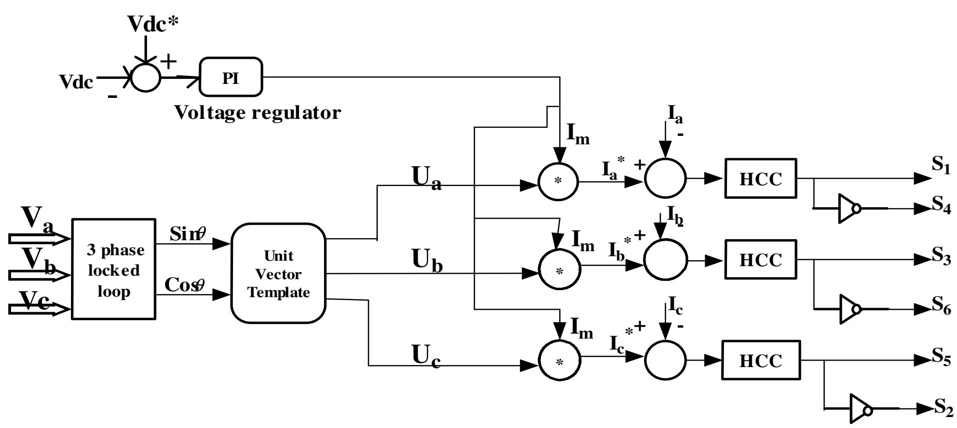

Fig.8.Block Diagram of Hysteresis Current Control for Three Phase VSI control.

In this system the hysteresis band is fixed over fundamental period, it is modelled mathematically as follows,

$i_{ref} = i_{max} sin\omega$

$i_{upper} = i_{ref} + H$

$i_{lower} = i_{ref} - H$

Where,

i_{ref}=Reference current.

i_{upper}=Upper Band

i_{lower}=Lower Band

H=Hysteresis band limit.

If $i_m > i_{upper}$, then $V_m = -{V_{dc}}/{2}$

If $i_m < i_{lower}$, then $V_m = {V_{dc}}/{2}$

ISSN: 2349-0845

IJRST

International Journal of Research in Science & Technology (IJRST)
Volume 1, Issue 2 : Page No. 1-10
www.ijrst.weebly.com

Where,
m= a, b, c phases
i =Load side current
V_{dc} = DC link voltage of inverter

The switching is done in such a way that generated signals remain within limits. The control system generates the reference signal which are compared with actual signal to generate gating signals. When signal crosses upper band, upper switch is turned OFF. When signal crosses lower band, lower switch is turned OFF. In this way actual signal is forced to track the reference signal within hysteresis band limit [7].

Figure 7 shows the Block diagram for hysteresis current control for three phase VSI control. The Reference DC voltage is compared with DC capacitor voltage and output is regulated through the PI controller which acts as a voltage regulator. This output provides the active current component I_m [6].

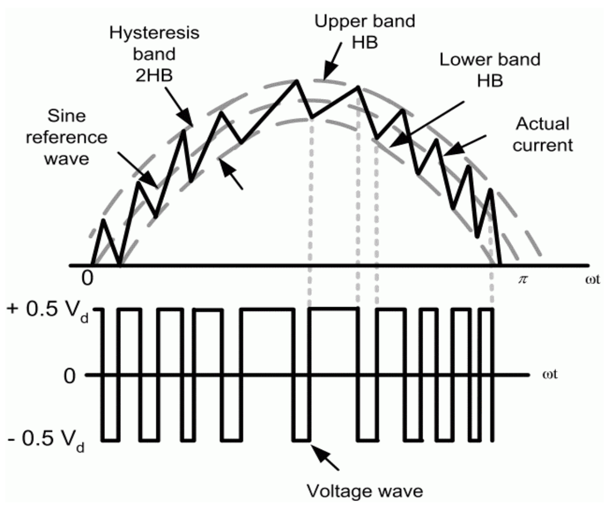

Fig.7.Basic Principal of hysteresis current controller.

$$V_{dc-error} = V_{dc^*} - V_{dc} \tag{11}$$

Three phase phase locked loop is used to generate Sinθ and Cosθ component by using three phase load side voltages. These components are used to generate voltage vector templates U_a, Ub, Uc.

$$U_a = \sin(\theta) \tag{12}$$

$$U_b = \sin(\theta - \frac{2\pi}{3}) \tag{13}$$

$$U_c = \sin(\theta + \frac{2\pi}{3}) \tag{14}$$

These templates are multiplied with active current component to generate reference currents $I_{a,}$ $I_{b,}$ I_c.

$$I_a{}^* = I_m * U_a \tag{15}$$

$$I_b{}^* = I_m * U_b \tag{16}$$

$$I_c{}^* = I_m * U_c \tag{17}$$

These reference currents then compared with actual load current and Error is processed through the hysteresis current controller to generate gate pulses.

ISSN: 2349-0845

These gate pulses controls the three phase Voltage Source Inverter (VSI).

$$I_{a\_error} = I_a * - I_a \tag{18}$$
$$I_{b\_error} = I_b * - I_b \tag{19}$$
$$I_{c\_error} = I_c * - I_c \tag{20}$$

The Switching pattern of IGBT switches can be modulated as per difference between reference current and actual current.

If
$I_{inverter} > I_{inverter} * - Hb$

Then Upper switch of inverter S1 is ON and Lower switch S4 is OFF.

If
$I_{inverter} < I_{inverter} * - Hb$

Then Lower switch of inverter S4 is ON and Upper switch of inverter S1 is OFF.

Where,

$I_{inverter}$ = Actual current of inverter.
$I_{inverter} *$ =Reference current of Inverter.
Hb = Hysteresis Band.

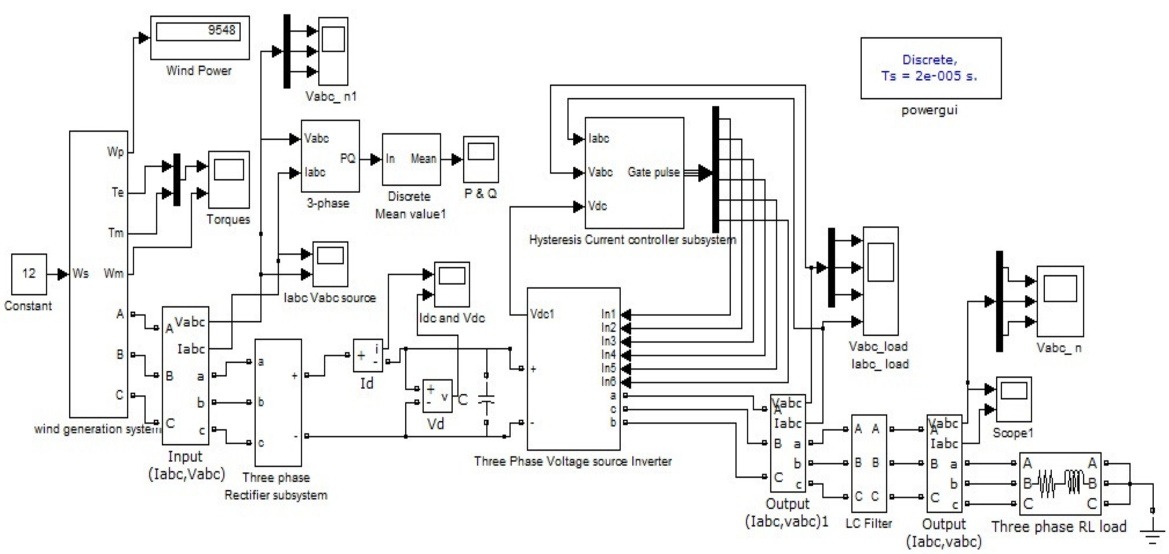

Fig.9. MATLAB Simulink model diagram.

IJRST
International Journal of Research in Science & Technology (IJRST)
Volume 1, Issue 2 : Page No. 1-10
www.ijrst.weebly.com
ISSN: 2349-0845

III. SIMULATION RESULTS:

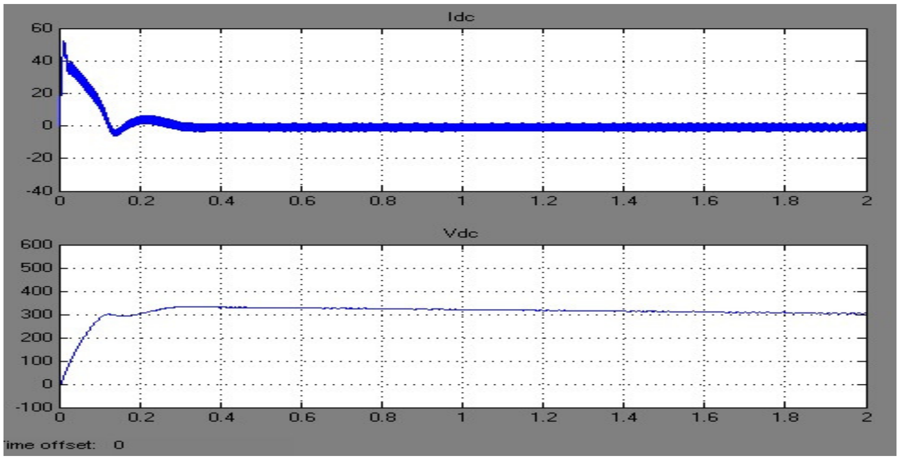

Fig.10. Output Voltage and current of rectifier.

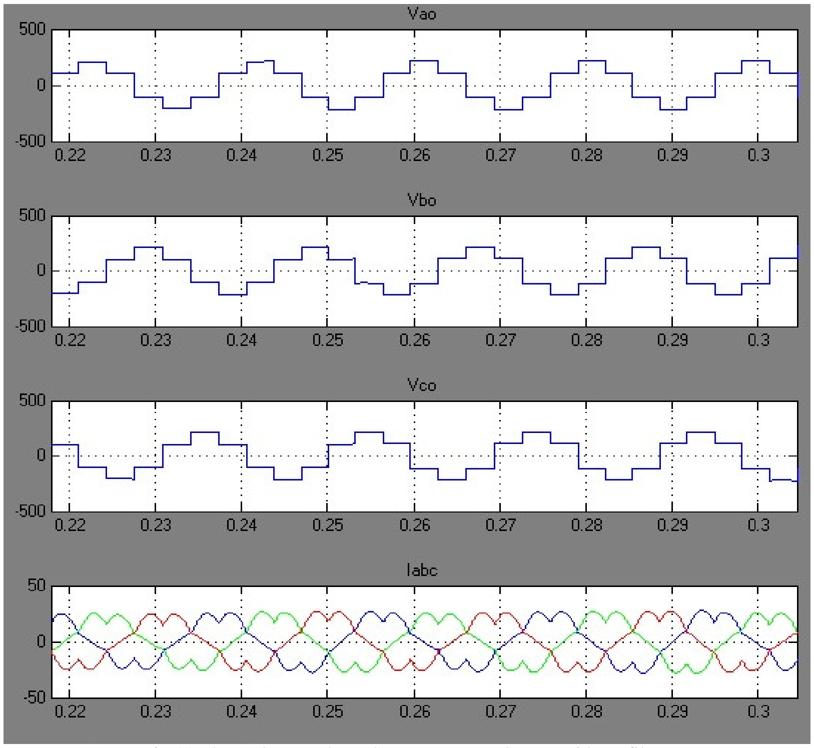

Fig.11.Three phase Voltage Source Inverter Output without filter.

IJRST

International Journal of Research in Science & Technology (IJRST)
Volume 1, Issue 2 : Page No. 1-10
www.ijrst.weebly.com

ISSN: 2349-0845

Figure 10 shows the three phase rectifier output. From that it is observed that DC current contains more harmonics than the DC voltage.Similarily figure 11 shows the load current and voltage output without filter. It is observed that it contains harmonics so we use filter to remove that harmonics. For this we use LC filter.

Figure 11 shows the load current and voltage waveforms with use of filter. From that it is observed that harmonic contains reduced than that of without filter condition. Filter used here is LC filter whose values are L=8e-3H, C=6e3F.

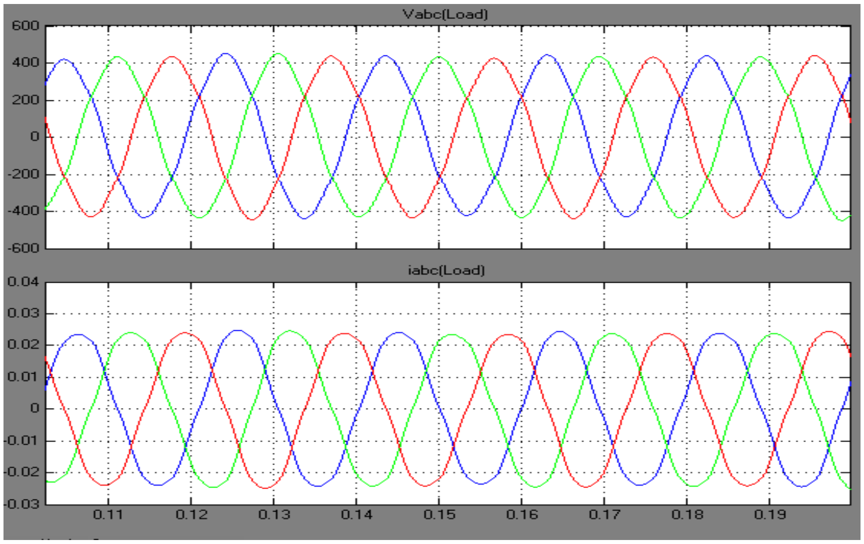

Fig.11.Three phase VSI output with filter.

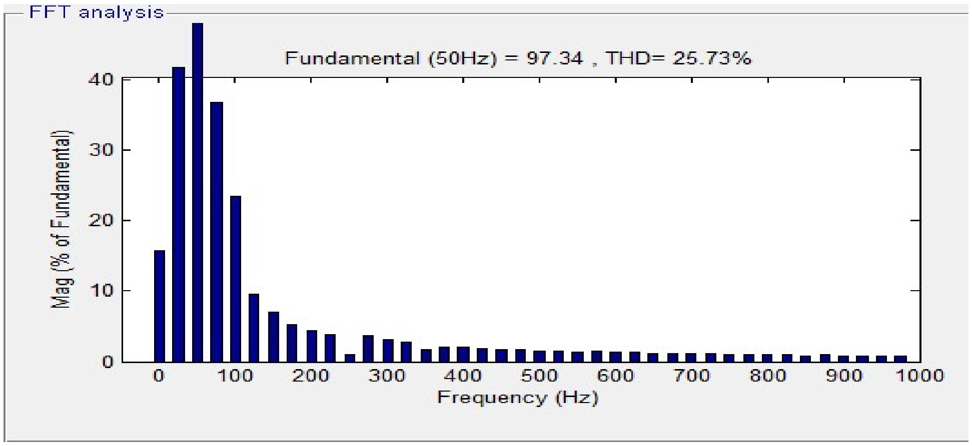

Fig.12. FFT analysis from MATLAB Simulink.

From figure 12 it is observed that THD =25.73.It shows that harmonic contains on load side reduced.

IV. CONCLUSION

This paper described the wind generator system with power converters. The Hysteresis current controller is used to control the voltage source inverter. Its performance has been analysed using MATLAB Simulink environment. The study also shows that a reasonable hysteresis-band control results in a reduced ripple and lower harmonic content. Moreover, due to incorporating of LC filter on the load side higher order harmonic current contents could be eliminated and it gives lower values of THD.

ISSN: 2349-0845

International Journal of Research in Science & Technology (IJRST)
Volume 1, Issue 2 : Page No. 1-10
www.ijrst.weebly.com

REFERENCES

[1] Mahmoud, M.Hussain. Mohamedn Orabi, and Mohamed M.Hamada (2013): Control of a Stand-alone variable speed wind Energy supply system.Appl.Sci.2013, 3,437 456: doi: 10.3390/app3020437.

[2] Aquilar.D; Azevedo.G; Rolan.A; Luna.A ;.(2009): Modeling of a Variable Speed Wind Turbine with Permanent Magnet Synchronous Generator. In proceeding of the IEEE International Symposium on Industrial Electronics, Seoul, korea.5-8 July 2009; pp.734-739.

[3] Bhende C.N; Mishra.S; Malla.S.G (2011): Permanent Magnet Synchronous Generators–based standalone wind energy supply system.IEEE Trans.Sust.Energy 2011, 2,361-373.E.Galvan. J.M.Carrasco, J.T.Bialasiewicz L.Gfranquelo. (2006): Power electronic system

[4] E.Galvan. J.M.Carrasco, J.T.Bialasiewicz L.Gfranquelo. (2006): Power electronic system for grid integration of renewable energy sources: A survey.IEEE Trans.On Ind.Electron., vol.53, no.4 pp.1002-1016, jun.2006.

[5] J. P. Pinto, J. L. Afonso, R. Pregitzer.(2007): "3-phase 4-wire shunt active power filter with renewable energy interface," presentedat the Conf. IEEE Renewable Energy & Power Quality, Seville, Spain, 2007.

[6] Ambrish ChandraS, Mukhtiar Singh, Vinod Khadkikar. (2011) Grid Interconnection of Renewable Energy Sources at the Distribution Level with Power-Quality Improvement Features. IEEE Trans.On Power Delivery vol.26, no.1, jan.2011.

[7] A. Mallikarjuna Prasad. B.Venkata Ranganadh, , Madichetty Sreedhar.(2013): Modelling And Simulation Of A Hysteresis Band Pulse Width Modulated Current Controller Applied To A Three Phase Voltage Source Inverter By Using Mat lab:IJAREEIE Vol.2 Issue9,sept 2013.

BIOGRAPHY

Pravin D. Kumbhar obtained his B.E degree from Annasaheb Dange Institute of Technology in the year 2012.Now he is pursuing his M.Tech degree from Walchand college of Engineering, Sangli, India. Under the guidance of Prof. S. S. Vanamane. His area of interest is power Electronics and Drives.

Mr. Chaitanya J. Kadam received B.E. Degree from R.I.T., Sakhrale, Shivaji University, Kolhapur. Currently He is pursuing M.Tech degree in Electrical power system. From Walchand College of Engineering, Sangli. His area of interest includes power electronics, multilevel inverters, and Power quality improvement.

Deepak R. Shelar obtained his B.E degree from Government College of Engineering, Jalgaon in the year 2011.Now he is pursuing his M.Tech degree from Walchand college of Engineering, Sangli, India. Under the guidance of Prof. S. S. Vanmane. His area of interest is power Electronics and power system protection.